LCDR Dylan Schmorrow, Ph.D
Information Processing Technical Office
Augmented Cognition: Building Cognitively Aware Computational Systems

Good Morning, I am LCDR Dylan Schmorrow. I want to share with you today one of DARPA's most exciting programs.

Imagine being able to put on a hat that could help us think and help us deal with the rapidly growing world of information flooding our lives. Maybe a decision hat—or situational awareness hat—something that would allow computers to know when our brains and bodies were ready for more information and how best to inform and interact with us; something that would allow computational systems to adapt to us, rather than always forcing us to adapt to them.

Imagine not being overwhelmed by a sea of information, not being paralyzed into inaction because of too much information, not getting the wrong kind of information and not getting the right kind of information too late. I don't know about you, but I need this today. I cannot imagine a future in which this capability does not exist. We must succeed in creating this capability and when we do we will have truly changed the world.

Ladies and Gentlemen, now I would like to share with you a video of my vision of the future.

<PLAY VIDEO - 4min 18 sec>

We are entering an era of unprecedented human advancement in which Darwinian principles of evolution may begin to show signs of artificial self-acceleration. Cutting edge, state-of-the-art scientific domains such as genetics, biomedical informatics, and cognitive psychology could, in fact, reduce today's accepted timeline of phylogeny from a few million years to a single human lifetime.

Granted, this requires revolutionary scientific leaps, but we should no longer consider ourselves in a position to discount these possibilities as mere science fiction.

My basic research ambition seeks to extend the cognitive abilities of humans, in essence helping us to be smarter and more efficient by developing technologies to augment human cognition. Let me start by suggesting that there are three basic methods of augmenting the human condition.

As a species we have already implemented two of these methods with varying degrees of success. First, humans began extending the body thousands of years ago through the use of clothing, hand tools, vehicles, and weapons. Second, humans began extending perception with eyeglasses, telescopes, and, more recently, with hearing aids, cameras, electron microscopes, night-vision goggles, and now retinal and cochlear implants.

However, it has only been within the past decade that the technologies needed to extend human cognition have emerged. Augmenting cognitive functions such as perception, comprehension, insight, and memory overtly transcend the traditional boundaries of the slowly evolving human mind and body.

Through the development of new computational systems and working in cooperation with these powerful systems, we are now able to peer through skin, muscle, and bone to observe functioning in the human brain and, for the first time, make sense of our observations.

Significant advances in the cognitive, behavioral, and brain sciences have been made over the past 10 years largely because of billions of dollars invested by the National Institutes of Health, the Office of Naval Research, and other federal agencies during a period of time known as the "Decade of the Brain." This investment in the 1990s focused on increasing our understanding of the basic scientific aspects of the human brain: namely, human cognition and human behavior.

Much of the work at these agencies is now focusing on follow-up efforts that will impact science and society in terms of clinical research. This research, however, has given DARPA an opportunity to take this knowledge and apply it in a different manner. Partly because technological advances have made brain imaging and science affordable to the research community, DARPA is now intensifying its focus on the brain, behavior, and cognition. The agency is pursuing research and technology in the aforementioned areas where both risk and payoff are very high. Success might provide dramatic advances for traditional military roles and missions.

Think of what "Moores Law"—broadly taken—has done for physics, biology and genomic research. These fields have been transformed. We are now at the dawn of a new era in the field of psychology where "Moores Law" will help transform brain and behavior science.

The DARPA Augmented Cognition program, in particular, is positioned at the intersection of two of DARPA's principle thrusts. The first focuses on the creation of new computers, sensors, and communication devices. The second thrust focuses on research relating to new biological and medical technologies. The synergy found where these thrusts converge will extend the use of elaborate new tools to the complex operational environments facing today’s and tomorrow's warfighters.

The focus within IPTO is now centered on developing cognitively aware computational systems that can sense and adapt to their users. The Augmented Cognition program is helping to lay the groundwork for implementing these tools in daily life and thereby will change forever the way technology and people interact. Many of the advances that have made the program possible have, in large part, been due to the affordability and use of tools such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). They have allowed for the elucidation of the spatial and temporal elements of neuronal activity.

These remarkable tools, although robust in the controlled environments of laboratories and hospitals, are not practical to field in operational environments. So, in order to extend the results provided from experiments using hospital and laboratory tools, the Augmented Cognition program strives to provide a unique focus on developing non-invasive, real-time detection of cognitive states and the use of automated technologies that leverage brain activity to modify and mediate cognition. On-line processing and analysis of cognitive state will allow computers to provide operational data in a manner specifically targeted to the user, and in a way that will not disrupt the user's current functions. This new interaction will be significantly more potent than the simple sum of a brain and a computer system—we will achieve an increase in the overall system IQ, capitalizing on the synergistic effect of this new human computer symbiosis.

So, how are we going to achieve this new paradigm? Well, this work requires a strong interdisciplinary effort with research drawing from neuroscience, bioengineering, materials science, information integration and human performance.

This vision will be accomplished by executing the program in four phases. The first phase is now underway—and we are currently developing and evaluating non-invasive technologies to enable the real-time detection of cognitive state. We are making good progress. The first major demonstration will occur at the end of this summer where we hope to showcase much of the technology we'd like to incorporate into further phases of the program.

Although the program has begun, we will be looking for additional performers who have strengths relating to our phase two efforts scheduled to start in fiscal year 2003. We'll be making information available for potential performers wanting to participate and for others who are interested in our developments via our web site as we progress.

I am now going to take a few minutes to discuss the objective of phase 1: detecting cognitive state in real time. This phase is focused on identifying cognitive-state shift detection in less than a minute or perhaps even a few seconds. As you might imagine, we have spent a lot of time trying to understand this fundamental challenge. As I mentioned earlier, wouldn't it be nice, and quite a bit more convenient, if we could just wear an augmented cognition hat?

Now, I don't have one of these hats in the trunk of my car—yet. But, if we peel back the layers on concepts such as decision-making and situational awareness, we find prototypical brain functions such as working memory at their core. And we now have devices that can read these brain functions and activity; not in my car, but back at the laboratory. We are able to track brain activity and have started to build a detailed understanding of how the brain processes information and how we can manipulate it. And it won't be long until this technology is in our cars—not in our trunks, but in the front seat helping us live safer lives through optimal human computer interaction.

These brain functions and related neural correlates are a doorway into the mind that allow us to build sensing devices and intelligent systems that will link brain function, cognition, and behavior so that the dynamic and autonomous manipulation of the knowledge world around us can be optimized.

For the real-time detection of cognitive state, measures will include the continuous monitoring of workload, inferences about current attentional focus, and ongoing cognition and intentions. Measures will also detect deleteriously high and low levels of arousal.

To do this requires new sensor technology equipment. Today's fMRI machines offer the highest spatial resolution for the study of human brain activity. However, their large size and weight makes both inadequate for measurements in real-world operational environments. Currently, EEG represents the only available portable, brain-imaging equipment suitable for this purpose; yet, it has the drawback of a relatively modest spatial resolution regarding the source localization of measured activity.

To overcome these restrictions, various technical approaches are being applied in Phase 1. I will now discuss three of these approaches:

1. The development of methods for the robust identification and discrimination of EEG signals correlated with specific cognitive processing. In addition to our ongoing work, an SBIR solicitation in this area has recently been released and is currently accepting submissions.

2. The development of wearable, optical imaging spectrometers to enable continuous, non-invasive, portable monitoring of the entire brain's neuronal and hemodynamic response. Using near-infrared light, it is possible to image the brain's neurovascular response by detecting the light scattered as a result of changes in blood oxygenation and neural firing. No one technology has yet achieved measurement of both of these biological events simultaneously throughout the entire brain—but we will. A second SBIR solicitation expanding this technology has recently been released and is also currently accepting submissions.

3. The enhancement of human cognitive capabilities by using multiple sensory channels, that is visual with auditory, visual with proprioceptive, and other combinations. To date there has not been a consistent approach to evaluating multi-channel exploitation for enhanced human cognitive performance.

This represents some of what we are doing today in Phase 1.

The second phase of the program, starting in fiscal year 03, focuses on MANIpulation of cognitive state.

Phase 2 tasks continue from the Phase 1 effort, however the emphasis is on being able to enhance human performance by bringing more of the human brain function on task. This will be accomplished through the exploitation of technologies proven effective in Phase 1. I believe that more is needed to develop systems that will ultimately improve human performance. In this phase we will begin to evaluate and quantify the capability of conceptual systems developed in phase 1 under greater cognitive load and stress.

Phase 3 will focus on automation techniques for enhancing human cognitive performance. This phase will demonstrate the autonomous manipulation of cognitive state under varying conditions of stress and will assess automation techniques for enhancing human cognitive performance and task accomplishment. Emphasis is on initial, cooperative prototype experimentation in conjunction with military battle experiments.

Increasingly complex scenarios involving tactical and strategic decision-making tasks under realistic time constraints will be employed to stress the humans and systems being evaluated.

Phase 4, the final phase, will focus on the relevant demonstration of cognitive state capabilities. The emphasis will be on a prototype designed for transition to operational environments. These advanced applications will be tailored to military problems in order to demonstrate potential pay-off for users. Success will improve the way 21st century warriors interact with computer-based systems and fundamentally re-engineer the military decision-making processes. Success will also change the human machine design paradigm from the human "learning the system" to the human and machine cooperating to solve problems and arrive at decisions.

The impact of this technology to the military services is both direct and formidable. These technologies have the potential to enhance operational capability currently beyond reach. This research will enable a single human being to monitor and control greater numbers of entities and processes. As such, this research program can lead to fewer persons being required to perform current functions. Military operators are often put into complex human-machine interactive environments that seem to be engineered to fail when a stressful situation is encountered. To help our nation's warriors better project power and improve readiness, we must develop technology to enhance human performance using intrinsic capabilities, that is to say, brain function.

In summary, the working premise of the Augmented Cognition Program is twofold. First, by knowing a person's cognitive state, we can maintain the state at an optimal arousal level. Second, by providing context via multiple channels and devices, such as auditory, haptics, spatial, and enhanced visualizations, we can enhance memory and cognition and thus improve the human's ability to perform optimally even under conditions of interruption and stress.

As a direct result of this research, we will enable the development of new computer systems, which are not just intuitive to the human user, but which will exhibit a cognitive awareness. I am convinced that the impact of this program will be of evolutionary significance—marking the beginning of a new symBIOTIC human-computer relationship. In the Information Processing Technology Office we are now at the threshold of a new era in which these cognitive systems will enable the ultimate formfitting interface: computers that can understand the cognitive state of their users and adapt to their needs. The Augmented Cognition program is part of this vision of the future—and will succeed in advancing human performance well beyond the 21st century.

Thank you.